CLAIMS

1. A spectrometer using a diffraction grating comprising:

a light-incident portion including an incident-side optical waveguide emitting a light beam that includes a plurality of wavelength components and that approximates a Gaussian beam, and a collimating lens that is arranged on an emission side of the incident-side optical waveguide and that converts the light beam approximating a Gaussian beam that is emitted from the incident-side optical waveguide into a substantially collimated light beam;

a diffraction grating having grooves on its surface, on which the light beam that has been converted into the substantially collimated light beam by the collimating lens is incident, the diffraction grating spectrally separating the light beam by emitting light beams whose emission direction depends on their wavelength; and

a light-emitting portion having a plurality of focusing lenses that respectively condense the light beams that have been spectrally separated by the diffraction grating;

wherein, when d is an effective diameter of the collimating lens and the focusing lenses, f is a focal length of the collimating lens and the focusing lenses, D is a physical outer diameter of the collimating lens and the focusing lenses, L is a distance between the diffraction grating and the focusing lenses, ϕ is an incident angle of the light beam with respect to the diffraction grating when the light beam is incident on the diffraction grating, NA is a numerical aperture of the incident-side optical waveguide, g_V is a length of the diffraction grating along a direction perpendicular to the grooves, g_P is a length of the diffraction grating along a direction parallel to the grooves, λ_1 and λ_2 are wavelengths of the adjacent incident light to be separated within the light beam incident on the diffraction grating, λ_0 is an average wavelength of the adjacent incident light of the wavelengths λ_1 and λ_2, and $\Delta\psi$ (in radian) is an angular difference of the diffraction angles at the diffraction grating between the light of the wavelength λ_1 and the light of the wavelength λ_2, then the following expressions are satisfied:

$$d \geq a$$

$$g_V \geq a/\cos\phi$$

$$g_P \geq a$$

$L \geq D/\Delta\psi$

where a is the larger value of $9\lambda_0/(\pi\Delta\psi)$ and 3f·NA.

2. A spectrometer using a diffraction grating comprising:

a light-incident portion including a planar light source having a uniform light intensity, and a collimating lens that converts a light beam having a plurality of wavelength components emitted from the planar light source into a substantially collimated light beam;

a diffraction grating having grooves on its surface, on which the light beam that has been converted into the substantially collimated light beam by the collimating lens is incident, the diffraction grating spectrally separating the light beam by emitting light beams whose emission direction depends on their wavelength; and

a light-emitting portion having a plurality of focusing lenses that respectively condense the light beams that have been spectrally separated by the diffraction grating;

wherein, when d is an effective diameter of the collimating lens and the focusing lenses, f is a focal length of the collimating lens and the focusing lenses, D is a physical outer diameter of the collimating lens and the focusing lenses, L is a distance between the diffraction grating and the focusing lenses, ϕ is an incident angle of the light beam with respect to the diffraction grating when the light beam is incident on the diffraction grating, w_1 is a radius of the planar light source, NA is a numerical aperture of the planar light source, g_V is a length of the diffraction grating along a direction perpendicular to the grooves, g_P is a length of the diffraction grating along a direction parallel to the grooves, λ_1 and λ_2 are wavelengths of the adjacent incident light to be separated within the light beam incident on the diffraction grating, and $\Delta\psi$ (in radian) is an angular difference of the diffraction angles at the diffraction grating between the light of the wavelength λ_1 and the light of the wavelength λ_2, then the following expressions are satisfied:

$d \geq 2f \cdot NA$

$f \geq 2w_1/\Delta\psi$

$g_V \geq 2f \cdot NA/\cos\phi$

$g_P \geq 2f \cdot NA$

$L \geq D/\Delta\psi$.

3. A spectrometer using a diffraction grating comprising:

a light-incident portion including an incident-side optical waveguide emitting a light beam that includes a plurality of wavelength components and that approximates a Gaussian beam, and a collimating lens that is arranged on an emission side of the incident-side optical waveguide and that converts the light beam approximating a Gaussian beam that is emitted from the incident-side optical waveguide into a substantially collimated light beam;

a diffraction grating having grooves on its surface, on which the light beam that has been converted into the substantially collimated light beam by the collimating lens is incident, the diffraction grating spectrally separating the light beam by emitting light beams whose emission direction depends on their wavelength; and

a light-emitting portion having a single focusing lens that condenses the light beams that have been spectrally separated by the diffraction grating, and a plurality of emission-side optical waveguides that respectively transmit the light beams that have been condensed by the focusing lens;

wherein, when d is an effective diameter of the collimating lens and the focusing lens, f is a focal length of the collimating lens and the focusing lens, ϕ is an incident angle of the light beam with respect to the diffraction grating when the light beam is incident on the diffraction grating, NA is a numerical aperture of the incident-side optical waveguide, s is a distance between the adjacent emission-side optical waveguides, g_V is a length of the diffraction grating along a direction perpendicular to the grooves, g_P is a length of the diffraction grating along a direction parallel to the grooves, λ_1 and λ_2 are wavelengths of the adjacent incident light to be separated within the light beam incident on the diffraction grating, λ_0 is an average wavelength of the adjacent incident light of the wavelengths λ_1 and λ_2, and $\Delta\psi$ (in radian) is an angular difference of the diffraction angles at the diffraction grating between the light of the wavelength λ_1 and the light of the wavelength λ_2, then the following expressions are satisfied:

$$d \geq a$$

$$g_V \geq a/\cos\phi$$

$$g_P \geq a$$

$$s = f \cdot \Delta\psi$$

where a is the larger value of $9\lambda_0/(\pi\Delta\psi)$ and $3f\cdot NA$.

4. A spectrometer using a diffraction grating comprising:

a light-incident portion including a planar light source having a uniform light intensity, and a collimating lens that converts a light beam having a plurality of wavelength components emitted from the planar light source into a substantially collimated light beam;

a diffraction grating having grooves on its surface, on which the light beam that has been converted into the substantially collimated light beam by the collimating lens is incident, the diffraction grating spectrally separating the light beam by emitting light beams whose emission direction depends on their wavelength; and

a light-emitting portion having a single focusing lens that condenses the light beams that have been spectrally separated by the diffraction grating, and a plurality of emission-side optical waveguides that respectively transmit the light beams that have been condensed by the focusing lens;

wherein, when d is an effective diameter of the collimating lens and the focusing lens, f is a focal length of the collimating lens and the focusing lens, ϕ is an incident angle of the light beam with respect to the diffraction grating when the light beam is incident on the diffraction grating, w_1 is a radius of the planar light source, NA is a numerical aperture of the planar light source, s is a distance between the adjacent emission-side optical waveguides, g_V is a length of the diffraction grating along a direction perpendicular to the grooves, g_P is a length of the diffraction grating along a direction parallel to the grooves, λ_1 and λ_2 are wavelengths of the adjacent incident light to be separated within the light beam incident on the diffraction grating, and $\Delta\psi$ (in radian) is an angular difference of the diffraction angles at the diffraction grating between the light of the wavelength λ_1 and the light of the wavelength λ_2, then the following expressions are satisfied:

$$d \geq 2f\cdot NA$$

$$f \geq 2w_1/\Delta\psi$$

$$g_V \geq 2f\cdot NA/\cos\phi$$

$$g_P \geq 2f\cdot NA$$

$$s = f\cdot\Delta\psi .$$

5. A spectrometer using a diffraction grating comprising:

a light-incident portion including an incident-side optical waveguide emitting a light beam that includes a plurality of wavelength components and that approximates a Gaussian beam, and a collimating lens that is arranged on an emission side of the incident-side optical waveguide and that converts the light beam approximating a Gaussian beam that is emitted from the incident-side optical waveguide into a substantially collimated light beam;

a diffraction grating having grooves on its surface, on which the light beam that has been converted into the substantially collimated light beam by the collimating lens is incident, the diffraction grating spectrally separating the light beam by emitting light beams whose emission direction depends on their wavelength; and

a light-emitting portion having a plurality of focusing lenses that respectively condense the light beams that have been spectrally separated by the diffraction grating, and emission-side optical waveguides on which the light that has been emitted from the focusing lenses is incident;

wherein, when d is an effective diameter of the collimating lens and d' is an effective diameter of the focusing lenses, f is a focal length of the collimating lens and f' is a focal length of the focusing lenses, D is a physical outer diameter of the collimating lens and D' is a physical outer diameter of the focusing lenses, L is a distance between the diffraction grating and the focusing lenses, ϕ is an incident angle of the light beam with respect to the diffraction grating when the light beam is incident on the diffraction grating, NA is a numerical aperture of the incident-side optical waveguide, NA' is a numerical aperture of the emission-side optical waveguide, g_V is a length of the diffraction grating along a direction perpendicular to the grooves, g_P is a length of the diffraction grating along a direction parallel to the grooves, λ_1 and λ_2 are wavelengths of the adjacent incident light to be separated within the light beam incident on the diffraction grating, λ_0 is an average wavelength of the adjacent incident light of the wavelengths λ_1 and λ_2, and $\Delta\psi$ (in radian) is an angular difference of the diffraction angles at the diffraction grating between the light of the wavelength λ_1 and the light of the wavelength λ_2, then the following expressions are satisfied:

$d \geq a$

$d' \geq a$

$g_V \geq a/\cos\phi$

$g_P \geq a$

$f' = f(NA/NA')$

$L \geq D'/\Delta\psi$

where a is the larger value of $9\lambda_0/(\pi\Delta\psi)$ and 3f·NA.

6. A spectrometer using a diffraction grating comprising:

a light-incident portion including a planar light source having a uniform light intensity, and a collimating lens that converts a light beam having a plurality of wavelength components emitted from the planar light source into a substantially collimated light beam;

a diffraction grating having grooves on its surface, on which the light beam that has been converted into the substantially collimated light beam by the collimating lens is incident, the diffraction grating spectrally separating the light beam by emitting light beams whose emission direction depends on their wavelength; and

a light-emitting portion having a plurality of focusing lenses that respectively condense the light beams that have been spectrally separated by the diffraction grating, and emission-side optical waveguides on which the light that has been emitted from the focusing lenses is incident;

wherein, when d is an effective diameter of the collimating lens and d' is an effective diameter of the focusing lenses, f is a focal length of the collimating lens and f' is a focal length of the focusing lenses, D is a physical outer diameter of the collimating lens and D' is a physical outer diameter of the focusing lenses, L is a distance between the diffraction grating and the focusing lenses, ϕ is an incident angle of the light beam with respect to the diffraction grating when the light beam is incident on the diffraction grating, w_1 is a radius of the planar light source, NA is a numerical aperture of the planar light source, NA' is a numerical aperture of the emission-side optical waveguide, g_V is a length of the diffraction grating along a direction perpendicular to the grooves, g_P is a length of the diffraction grating along a direction parallel to the grooves, λ_1 and λ_2 are wavelengths of the adjacent incident light to be separated within the light beam incident on the diffraction grating, and $\Delta\psi$ (in radian) is an angular difference of the diffraction angles at the

diffraction grating between the light of the wavelength λ_1 and the light of the wavelength λ_2, then the following expressions are satisfied:

$$d \geq 2f \cdot NA$$

$$d' \geq 2f' \cdot NA'$$

$$f \geq 2w_1/\Delta\psi$$

$$g_V \geq 2f \cdot NA/\cos\phi$$

$$g_P \geq 2f \cdot NA$$

$$f' = f(NA/NA')$$

$$L \geq D'/\Delta\psi .$$

7. A spectrometer using a diffraction grating comprising:

a light-incident portion including an incident-side optical waveguide emitting a light beam that includes a plurality of wavelength components and that approximates a Gaussian beam, and a collimating lens that is arranged on an emission side of the incident-side optical waveguide and that converts the light beam approximating a Gaussian beam that is emitted from the incident-side optical waveguide into a substantially collimated light beam;

a diffraction grating having grooves on its surface, on which the light beam that has been converted into the substantially collimated light beam by the collimating lens is incident, the diffraction grating spectrally separating the light beam by emitting light beams whose emission direction depends on their wavelength; and

a light-emitting portion having a single focusing lens that condenses the light beams that have been spectrally separated by the diffraction grating, and a plurality of emission-side optical waveguides that respectively transmit the light beams that have been condensed by the focusing lens;

wherein, when d is an effective diameter of the collimating lens and d' is an effective diameter of the focusing lens, f is a focal length of the collimating lens and f' is a focal length of the focusing lens, ϕ is an incident angle of the light beam with respect to the diffraction grating when the light beam is incident on the diffraction grating, NA is a numerical aperture of the incident-side optical waveguide, NA' is a numerical aperture of the emission-side optical waveguide, s is a distance between the adjacent emission-side optical waveguides, gv is a length of the diffraction grating along a direction perpendicular to the

grooves, g_P is a length of the diffraction grating along a direction parallel to the grooves, λ_1 and λ_2 are wavelengths of the adjacent incident light to be separated within the light beam incident on the diffraction grating, λ_0 is an average wavelength of the adjacent incident light of the wavelengths λ_1 and λ_2, and $\Delta\psi$ (in radian) is an angular difference of the diffraction angles at the diffraction grating between the light of the wavelength λ_1 and the light of the wavelength λ_2, then the following expressions are satisfied:

$$d \geq a$$

$$d' \geq a$$

$$g_V \geq a/\cos\phi$$

$$g_P \geq a$$

$$f' = f(NA/NA')$$

$$s = f' \cdot \Delta\psi$$

where a is the larger value of $9\lambda_0/(\pi\Delta\psi)$ and $3f \cdot NA$.

8. A spectrometer using a diffraction grating comprising:

a light-incident portion including a planar light source having a uniform light intensity, and a collimating lens that converts a light beam having a plurality of wavelength components emitted from the planar light source into a substantially collimated light beam;

a diffraction grating having grooves on its surface, on which the light beam that has been converted into the substantially collimated light beam by the collimating lens is incident, the diffraction grating spectrally separating the light beam by emitting light beams whose emission direction depends on their wavelength; and

a light-emitting portion having a single focusing lens that condenses the light beams that have been spectrally separated by the diffraction grating, and a plurality of emission-side optical waveguides that respectively transmit the light beams that have been condensed by the focusing lens;

wherein, when d is an effective diameter of the collimating lens and d' is an effective diameter of the focusing lens, f is a focal length of the collimating lens and f' is a focal length of the focusing lens, ϕ is an incident angle of the light beam with respect to the diffraction grating when the light beam is incident on the diffraction grating, w_1 is a radius of the planar light source, NA is a numerical aperture of the planar light

source, NA' is a numerical aperture of the emission-side optical waveguide, s is a distance between the adjacent emission-side optical waveguides, g_V is a length of the diffraction grating along a direction perpendicular to the grooves, g_P is a length of the diffraction grating along a direction parallel to the grooves, λ_1 and λ_2 are wavelengths of the adjacent incident light to be separated within the light beam incident on the diffraction grating, and $\Delta\psi$ (in radian) is an angular difference of the diffraction angles at the diffraction grating between the light of the wavelength λ_1 and the light of the wavelength λ_2, then the following expressions are satisfied:

$$d \geq 2f \cdot NA$$
$$d' \geq 2f' \cdot NA'$$
$$f \geq 2w_1/\Delta\psi$$
$$f' = f(NA/NA')$$
$$g_V \geq 2f \cdot NA/\cos\phi$$
$$g_P \geq 2f \cdot NA$$
$$s = f' \cdot \Delta\psi .$$

9. The spectrometer according to any of claims 1 to 8, wherein the diffraction grating's surface on which the light beam is incident is substantially rectangular or substantially elliptical.

10. The spectrometer according to any of claims 1 to 8, wherein the collimating lens and the focusing lenses are rod lenses having a refractive index distribution along their radial direction.

11. The spectrometer according to any of claims 1 to 8, wherein the diffraction grating is a substrate having grooves of parallel relief in its surface, the groove's vertical cross-sectional shape being substantially rectangular.

12. The spectrometer according to any of claims 1 to 8, wherein the diffraction grating is a two-dimensional photonic crystal having grooves of parallel relief in its surface, the groove's vertical cross-sectional shape being substantially rectangular.